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Tools to Study Interfaces for Superconducting,Thermoelectric, and Magnetic Materials

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The AFOSR support has enabled us to acquire tools to study interfaces in superconducting, thermoelectric, and magnetic materials, including a custom-designed fully integrated growth and characterization system and in situ tools to be integrated into our existing high-resolution transmission electron microscope (TEM). In order to precisely fabricate and characterize materials with prescribed interfaces, we have purchased major components parts to build a specially designed highly versatile molecular beam epitaxy (MBE) system with two satellite chambers for in situ scanning tunneling microscopy (STM) and magnetization/transport measurements. The MBE system, which grows crystalline thin films in ultrahigh vacuum (UHV) with precise control of thickness, composition, and morphology, will be used to synthesize and study the interfaces between various materials guided by theoretical model calculations. The two satellite chambers will be used to study the electronic spectroscopy and the defect, magnetic, and transport properties of the interfaces. The project will enable us to construct and identify the crucial roles of interfaces in their physical and chemical characteristics, which have been demonstrated to dictate the behavior of materials and devices on different scales. As soon

15. SUBJECT TERMS

High Temperature Superconductivity; Superconductivity; Thermoelectrics; Magnetic Materials

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AFOSR Final Report: 8/28/2014 - 8/27/2016
Title: Tools to Study Interfaces for Superconducting, Thermoelectric, and Magnetic Materials at the University of Houston
Grant Number: FA2386-14-1-3007
PI: Dr. Ching-Wu Chu
co-PIs: Dr. Shuo Chen, Dr. Bing Lv, Dr. Zhifeng Ren
Program Manager: Dr. Harold Weinstock

Acquired Equipment

CreaTec custom-designed fully integrated growth (MBE) and characterization (AFM/STM, ARPES, magneto-resistance) system	$	1,146,875.00
Leica M205 C Stereomicroscope	$	30,511.72
Quantum Design cryogen-free MPMS3 SQUID Magnetometer system	$	82,802.70*
Gatan Precision Ion Polishing System (PIPS) II	$	90,817.20
Angstrom Scientific Wildfire D6-J double tilt holder temperature control suite	$	59,055.00
Gatan CCD Camera	$	99,897.70
Agilent Spectrophotometer	$	69,494.68
Dynapower DC power supply	$	36,581.00
Hummingbird Precision Machine NanoManipulation Holder for JEOL 2010F TEM	$	140,150.00
MTI Furnace	$	4,994.00
MBraun Rotary Pump	$	2,065.64
Bio-logic SP-150	$	8,694.17
Bio-logic rotating disk electrode system	$	6,063.74
Landt battery testers	$	9,928.00
Bio-logic SP-200	$	10,242.50
Allied M-Prep 5 Grinder/Polisher	$	3,557.95
AJA International 600 Watt RF generator	$	11,581.00
TOTAL	**$**	**1,813,312.00**

*The total cost of the Quantum Design MPMS3 SQUID Magnetometer system is $538,402.00. A portion is considered cost-sharing for ex situ sample measurement in the current project.

Summary of Research and Education Projects for which Acquired Equipment will be used

- The MBE system, which grows crystalline thin films in ultrahigh vacuum (UHV) with precise control of thickness, composition, and morphology, will be used to synthesize and study the interfaces between various materials guided by theoretical model calculations.
- The two satellite chambers will be used to study the electronic spectroscopic, defect, magnetic, and transport properties of the interfaces.
- We will construct and identify the crucial roles of interfaces in their physical and chemical characteristics, which have been demonstrated to dictate the behavior of materials and devices on different scales.
- The MTI furnace and MBraun rotary pump are the key components of a chemical vapor deposition system that will be used to produce nanostructural materials with interfaces. The Dynapower DC power supply will be used to synthesize composite materials with

controllable amounts and structures of interfaces. The AJA International 600 Watt RF generator will be used on our sputtering system to fabricate thin films with interfaces.

- The electronic structures of these materials will be investigated using the Agilent Spectrophotometer. The ex situ electrical and electrochemical studies on the materials will be carried out with the electrochemical workstation (Bio-logic SP-150, Bio-logic rotating disk electrode system, and Landt battery testers).
- As soon as prescribed interfaces between materials are synthesized, we will elucidate the most fundamental questions of the composition and structure for understanding and facilitating the properties of the bulk materials and devices with these interfaces by integrating the acquired in situ tools into our existing transmission electron microscope (TEM): a high-resolution CCD camera; a liquid nitrogen cryo holder; a low noise electrical biasing holder and a high precision electrochemical workstation (Bio-logic SP-200) as the power supply; and a DENSsolutions (distributed by Angstrom Scientific Inc.) Wildfire D6-J double tilt high temperature holder.
- To prepare the TEM samples for atomic resolution imaging, an Allied M-Prep 5 Grinder/Polisher, a Leica M205 C Stereomicroscope, and a Gatan Precision Ion Polishing System (PIPS) II have been acquired. The stereomicroscope will also be used to examine the macrostructures of the interfaces
- Some initial microstructure characterizations have been carried out on materials with interfaces, such as various thermoelectric composite materials, battery materials, and $CaFe_2As_2$ samples.
- We will encourage our graduate and undergraduate students and postdocs to become self-users on these tools so that they can gain more knowledge and also learn more directly from hands-on experiences by using these tools.
- The new instruments will serve as state-of-the-are research tools for the PI's and co-PIs' postdocs and graduate students and also as advanced teaching tools to demonstrate and explain observation, manipulation, and property investigation down to the atomic scale for undergraduate courses and various outreach programs.

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FA2386-14-1-3007

Principal Investigator Name

The full name of the principal investigator on the grant or contract.

Ching-Wu Chu

Program Officer

The AFOSR Program Officer currently assigned to the award

Dr. Harold Weinstock

Reporting Period Start Date

08/28/2014

Reporting Period End Date

08/27/2014

Abstract

The AFOSR support has enabled us to acquire tools to study interfaces in superconducting, thermoelectric, and magnetic materials. The acquired equipment includes a custom-designed fully integrated growth and characterization system and in situ tools to be integrated into our existing high-resolution transmission electron microscope (TEM). In order to precisely fabricate and characterize materials with prescribed interfaces, we have purchased major components parts to have built with the vendor a specially designed highly versatile molecular beam epitaxy (MBE) system with two satellite chambers for in situ scanning tunneling microscopy (STM) and magnetization/transport measurements. The MBE system, which grows crystalline thin films in ultrahigh vacuum (UHV) with precise control of thickness, composition, and morphology, will be used to synthesize and study the interfaces between various materials guided by theoretical model calculations. The two satellite chambers will be used to study the electronic spectroscopy and the defect, magnetic, and transport properties of the interfaces. The project will enable us to construct and identify the crucial roles of interfaces in their physical and chemical characteristics, which have been demonstrated to dictate the behavior of materials and devices on different scales. The two best MBE

groups in the world, headed by Ivan Bozovic at Brookhaven National Lab and Qi-Kun Xue at Tsinghua University in Beijing, respectively, have expressed their willingness to collaborate in our interface efforts. Additionally, the recognition of interface effects has been growing, as evidenced by the recent Nature report on our interface work. As soon as the prescribed interfaces between materials are synthesized, we will elucidate the most fundamental questions of the composition and structure for understanding and facilitating the properties of the bulk materials and devices with these interfaces by integrating acquired in situ tools into our existing transmission electron microscope (TEM): a high-resolution CCD camera; a low noise electrical biasing holder with a high precision power supply; and a double tilt high temperature holder. Some initial microstructure characterizations have been carried out on materials with interfaces, such as various thermoelectric composite materials, battery materials, and CaFe2As2 samples. We will encourage our graduate and undergraduate students and postdocs to become self-users on these tools so that they can gain more knowledge and also learn more directly from hands-on experiences by using these tools, and the new instruments will serve as advanced teaching tools to demonstrate and explain observation, manipulation, and property investigation down to the atomic scale for undergraduate courses and various outreach programs.

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None

Change in AFOSR Program Officer, if any:

None

Extensions granted or milestones slipped, if any:

A one-year no-cost extension was granted.

AFOSR LRIR Number

LRIR Title

Reporting Period

Laboratory Task Manager

Program Officer

Research Objectives

Technical Summary

Funding Summary by Cost Category (by FY, $K)

	Starting FY	FY+1	FY+2
Salary			
Equipment/Facilities			
Supplies			
Total			

Report Document

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Appendix Documents

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